SUPER TYPHOONS IVAN (27W) AND JOAN (28W)

I. HIGHLIGHTS

Super Typhoon Ivan (27W) and Super Typhoon Joan (28W) were two of three tropical cyclones (TCs) in the western North Pacific (WNP) during 1997 to attain an extreme intensity of 160 kt (82 m/sec), and were the 8th and 9th super typhoons of 1997's unprecedented annual total of eleven. They reached their peak intensities at nearly the same time: Ivan at 171800Z October and Joan at 170600Z October. At 171200Z, Ivan was at 155 kt (80 m/sec) while Joan was still at 160 kt (82 m/sec); the first observation of two TCs of such extreme intensity existing simultaneously in the WNP. Both Ivan and Joan affected the Mariana Islands, and Ivan was the first and only TC during 1997 of at least tropical storm intensity to make landfall on Luzon. An equatorial westerly wind burst (bounded by twin near-equatorial troughs) preceded the formation of Ivan, Joan and a Southern Hemisphere twin, TC 02P (Lusi).

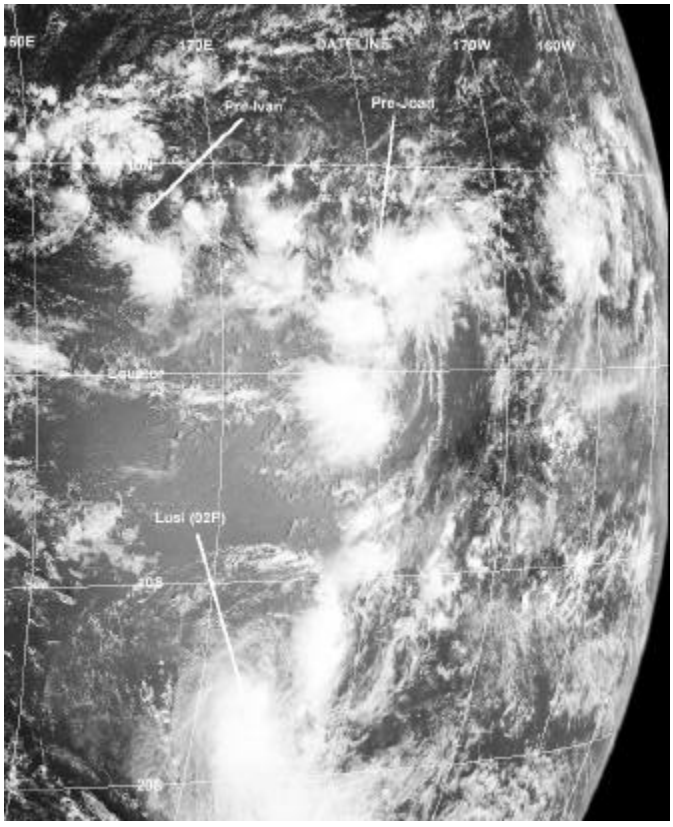


Figure 3-27/28-1 The pre-Ivan and pre-Joan tropical disturbances are poorly organized at low latitude in the eastern portion of the WNP basin. A Southern Hemisphere twin, Lusi, is passing southward between Fiji and the islands of Vanuatu (102132Z October visible GMS imagery).

II. TRACK AND INTENSITY

During the first week of October, low-latitude, low-level, westerly winds blew along the equator from approximately 150E eastward, across the international dateline (IDL), to near 170W. Twin near-equatorial troughs (one in the Northern Hemisphere, the other in the Southern Hemisphere) bounded these westerly winds and a region of deep convection. As the deep convection along the equator diminished, three TCs emerged from this synoptic flow pattern. The first -- Lusi -- formed in the Southern Hemisphere on 08 October and moved southward between Fiji and Vanuatu. On 13 October, Ivan and Joan formed in the Northern Hemisphere in the eastern half of Micronesia and began to track toward the west-northwest. As they were initially poorly organized (Figure 3-27/28-1) and isolated in an environment relatively free of deep convection (Figure 3-27/28-2), neither numerical guidance nor human forecaster anticipated the extreme intensity which these two TCs would attain. Also lacking during the lifetimes of the two TCs was any significant monsoon flow to their south and west.

a. STY Ivan (27W)

Ivan (the westernmost of the pair) originated from a very poorly organized tropical disturbance in the near-equatorial trough that stretched across the eastern Caroline and Marshall Island groups (see Figure 3-27/28-1). It was first mentioned on the 110600Z October Significant Tropical Weather Advisory (ABPW), when animated satellite imagery and synoptic data indicated the presence of a low-level circulation in association with an area of deep convection near 6N 165E. The pre-Joan tropical disturbance, located further to the east, was also first noted on this advisory.

With an increase in the organization and coverage of deep convection, a Tropical Cyclone Formation Alert (TCFA) was issued valid at 120800Z October as the pre-Ivan tropical disturbance (TD) moved rapidly (18 kt / 33 km/hr) west- northwest on a track which, if extrapolated, would pass just to the south of Guam. Based upon intensity estimates from satellite, the first warning on TD 27W was issued valid at 130600Z. There was still no expectation of any significant intensification, and remarks on the first warning indicated that the system was expected to intensify at a less than climatological rate. See the Discussion Section for further comments on Ivan (and Joan's) intensification. With increased banding of the deep convection, TD 27W was upgraded to Tropical Storm Ivan (27W) at 131800Z. Visible imagery on the morning of 14 October (Figure 3-27/28-3) gave clear indication of Ivan's location to the east-southeast of Guam. Passing 55 nm (102 km) to the south of Guam on the night of 14 October, Ivan's circulation center was well-defined on Guam's NEXRAD. A velocity cross section through Ivan's "eye" at 141120Z showed, at azimuth and range of 139 degrees and 75 nm (139 km) respectively, a maximum inbound velocity of 47 kt (24 m/sec) at 7,000 ft (210 m) (the lowest observable altitude); and, at azimuth 148 degrees and 79 nm (146 km) respectively, a

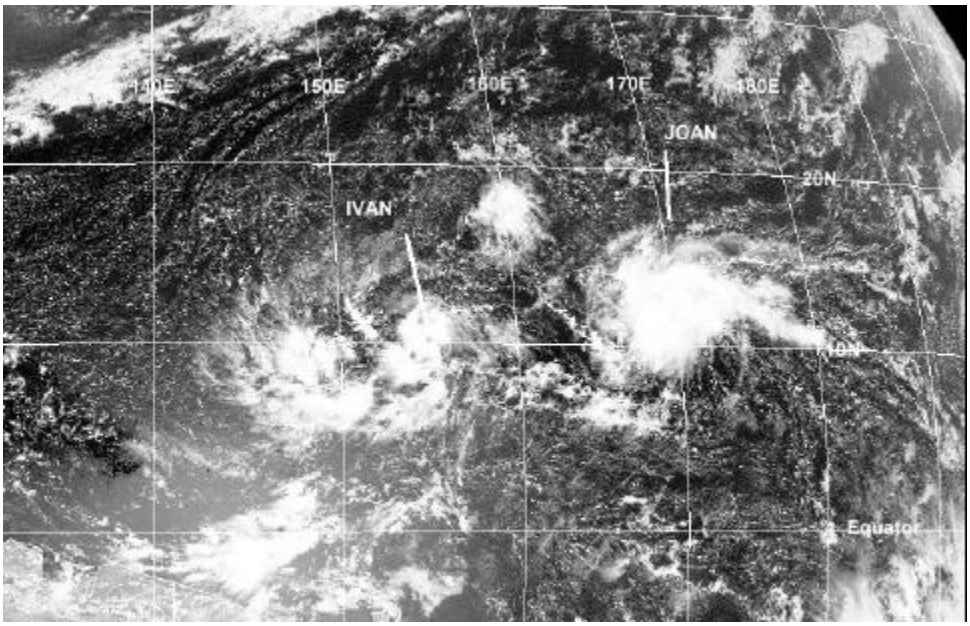


Figure 3-27/28-2. A high-contrast visible image shows the relative isolation of Ivan and Joan as they emerged from the near equatorial trough and moved west-northwestward across the relatively cloud-free basin (130132Z October visible GMS imagery).

maximum outbound velocity of 42 kt (22 m/sec), also at 7,000 ft (210 m). After passing Guam, Ivan became a typhoon at 150600Z, and then began to intensify at a fast rate (1.5 T numbers per day) (Figure 3-27/28-4). During the 48-hour period from 150600Z to 170600Z Ivan intensified from 65 kt (33 m/sec) to 145 kt (75 m/sec) approximately 3 T-numbers. The peak intensity of 160 kt (82 m/sec) was reached at 171800Z. On 16 October, Ivan slowed and began to track toward Luzon. Numerical guidance and the synoptic flow pattern suggested that the TC would recurve before reaching the Philippines. The anticipated northward turn did commence on 18 October, but it was too late to spare the Philippines. At approximately 191800Z October, the

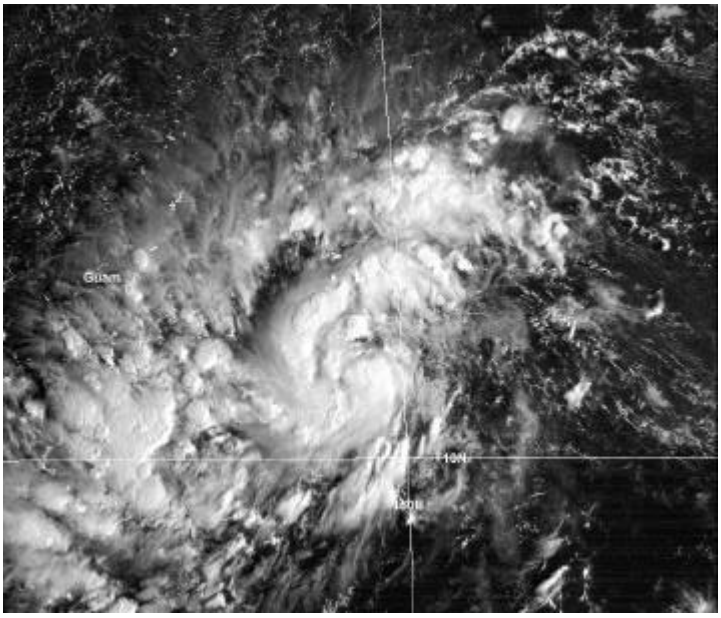


Figure 3-27/28-3 Ivan approaches Guam after becoming a tropical storm (132132Z October visible GMS imagery).

center of Ivan made landfall on the extreme northeastern tip of Luzon with an intensity of 120 kt (62 m/sec). On 20 October, the typhoon moved into the Luzon Strait and recurved. After recurving, it dropped below typhoon intensity on 21 October, then briefly reintensified to typhoon intensity on 22 October as it moved northeastward south of Okinawa. A steady weakening trend then set in, and the final warning was issued, valid at 241200Z, as the system became extratropical.

b. Joan (28W)

Joan (the easternmost of the Ivan-Joan pair) originated from a very poorly organized tropical disturbance in a near-equatorial trough that stretched across the eastern Caroline and Marshall Island groups (see Figure 3-27/28-1). The system was first mentioned on the 110600Z October ABPW. Animated satellite imagery and synoptic data indicated the possible presence of a low-level circulation in association with an area of deep convection at a low latitude near 4N 176E. Synoptic data indicated that equatorial westerlies were present to the south of this disturbance. The pre-Ivan tropical disturbance -- located further to the west -- was also first noted on this advisory. The pre-Joan tropical disturbance moved northwestward, and was north of 10N by 13

October. With an increase in the areal coverage and organization of deep convection, a TCFA was issued valid at 130400Z October.

The system now made a turn to the left and began to track to the west and slowly intensify. The first warning on TD 28W was issued, valid at 130600Z, based on satellite intensity estimates of 25 kt (13 m/sec). The system was expected to intensify at a climatological rate. Based upon satellite intensity estimates of 35 kt (18 m/sec), TD 28W was upgraded to Tropical Storm Joan (28W) on the warning valid at 140600Z. The system now tracked just north of due west, approached the Mariana Islands, and intensified. After becoming a typhoon, between 151200Z and 151800Z, Joan began to intensify very rapidly, increasing from 70 kt (36 m/sec) at 151800Z to its peak of 160 kt (82 m/sec) 36 hours later (Figure 3-27/28-5a,b). The equivalent pressure fall of 100 mb over this 36-hour period, for an average of 2.8 mb per hour, qualifies as a case of explosive deepening (Dunnavan 1981). As it approached the Mariana Islands, Joan made turned to the northwest. Weakening slightly, it passed between the Islands of Saipan and Anatahan on the morning of 18 October (see the Impact Section for details on the effects of Joan on the Marianas). Its well-defined eye was tracked by Guam's NEXRAD as it passed to the north. However, at a range of 155 nm (287 km) from the site, it was beyond Doppler radial velocity range. Joan remained at or above the super typhoon threshold (130 kt, 67 m/sec) for 4.5 days (170000Z to 211200Z) -- a record. Moving slowly, but making a sharp recurve during the 48-hour period 200000Z to 220000Z, Joan weakened steadily from 140 kt (72 m/sec) to 115 kt (59 m/sec). On 23 October, Joan moved eastward along 30N and continued to weaken. On 24 October, the system turned toward the northeast and accelerated. The final warning was issued, valid at 240000Z, when it appeared that Joan was transitioning into an intense extratropical low. In postanalysis, Joan remained at typhoon intensity until 241800Z, and its transition into an extratropical low was completed at 251800Z.

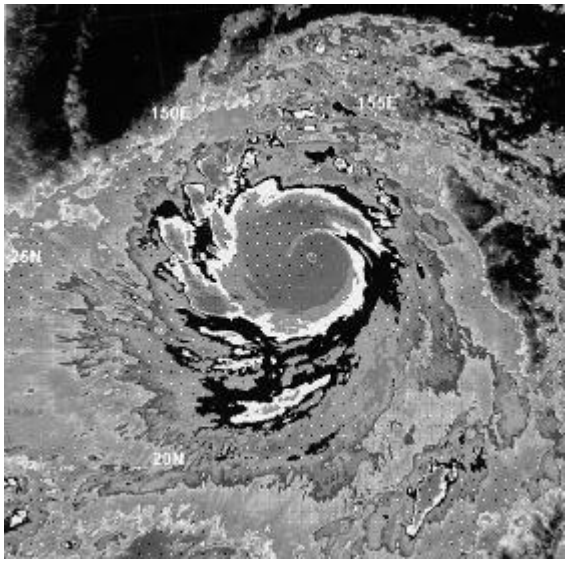


Figure 3-27/28-4 Ivan becomes the year's eighth super typhoon (161913Z October enhanced IR DMSP imagery). Enhancement curve is "BD".

III. DISCUSSION

a. On the extreme intensities reached by Ivan and Joan

Ivan and Joan both emerged from a near equatorial trough in the Marshall Islands. As the two TCs moved west-northwestward in tandem, they both intensified to an extreme value of 160 kt (82 m/sec) -- two of three WNP TCs to do so during 1997 (the other was STY Paka (05C)). At 171200Z, Ivan was at 155 kt (80 m/sec) while Joan was still at 160 kt (82 m/sec); the first time noted that two TCs of such extreme intensity existed simultaneously in the WNP basin (Figure 3-27/28-6a,b). On the enhanced infrared image of Figure 3-27/28-5b, Joan's cold dark-gray eye

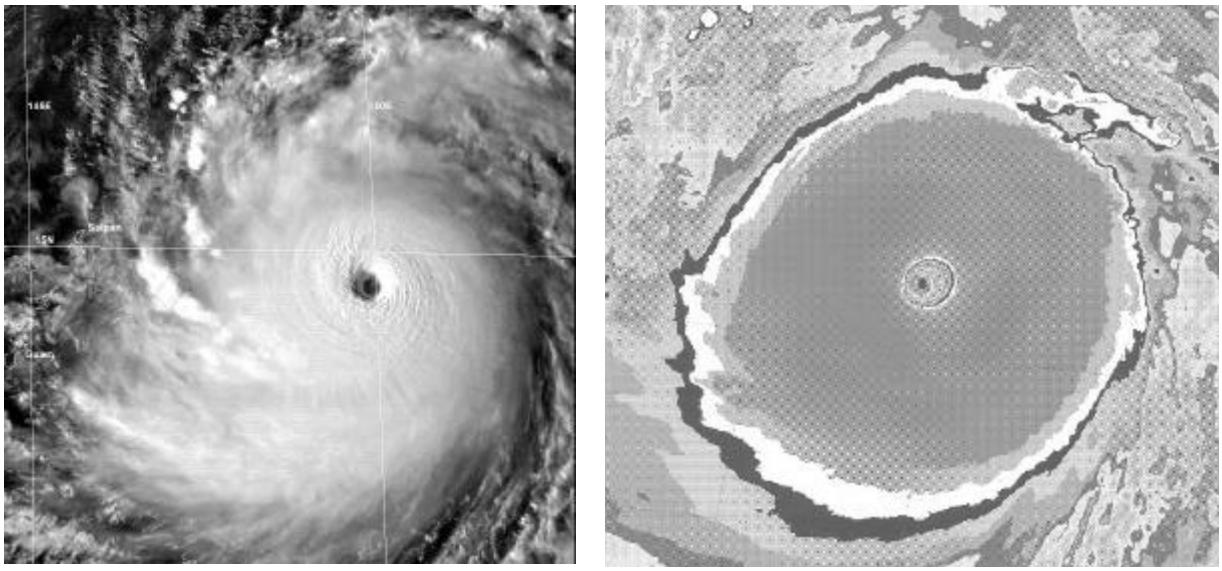


Figure 3-27/28-5 Joan reaches its peak intensity of 160 kt (82 m/sec). (a) The low sun-angle of late afternoon helps highlight features on the tops of Joan's eye wall cloud (170632Z October visible GMS imagery). (b) The cold dard gray ring surrounding Joan's eye-indicative of temperatures of -81C or colder-puts Joan off the scale of Dvorak's intensity estimation techniques using enhanced IR imagery (170803Z October enhanced IR DMSP imagery). Enhancement curve is "BD"

wall cloud (indicating cloud-top temperatures of -81 degrees C or colder), is off of Dvorak's scale for subjectively determining TC intensity from infrared imagery (Dvorak 1984). The Digital Dvorak (DD) algorithm, however, has no intrinsic upper bound (although there may be actual physical upper limits), and the DD numbers for both Ivan and Joan (Figure 3-27/28-7a,b) reached T8.0 (hypothetically equivalent to 170 kt (87 m/sec) intensity). Since 1995, the highest DD number computed for a typhoon by the DD algorithm on the satellite image processing equipment at JTWC was T8.3 for Super Typhoon Angela (29W) (1995), as it approached the Philippines. No other TC since then has reached a DD number of 8.0 or higher. Why these two TCs became so intense is unknown. Early in their lives, neither objective guidance nor human forecaster anticipated the extreme intensities that Ivan and Joan would reach. The initial disturbances from which they developed were very poorly organized and were isolated in an environment that was unusually free of deep convection. The monsoon trough across the WNP was relatively weak and sea-level pressures were near or above normal. For Ivan, nearly every intensity forecast leading up to its peak was low by as much as 40 kt (21 m/sec) for the 12-hour forecast, and 45, 50, 45, and 50 kt for the 24-, 36-, 48-, and 72-hour forecasts respectively. For Joan, the intensity forecasts were even lower: nearly all forecasts for the entire life of the TC were too low. Leading up to its peak, the intensity forecasts for Joan were low by as much as 30, 55, 65, 65, and 65 kt for the 12-, 24-, 36-, 48-, and 72-hour forecasts respectively. Despite the passage of these two TCs across much of the WNP basin, the monthly average wind for October (Figure 3-3) was more easterly than normal everywhere except in the low-latitudes east of 150E (an El Niño-related anomaly).

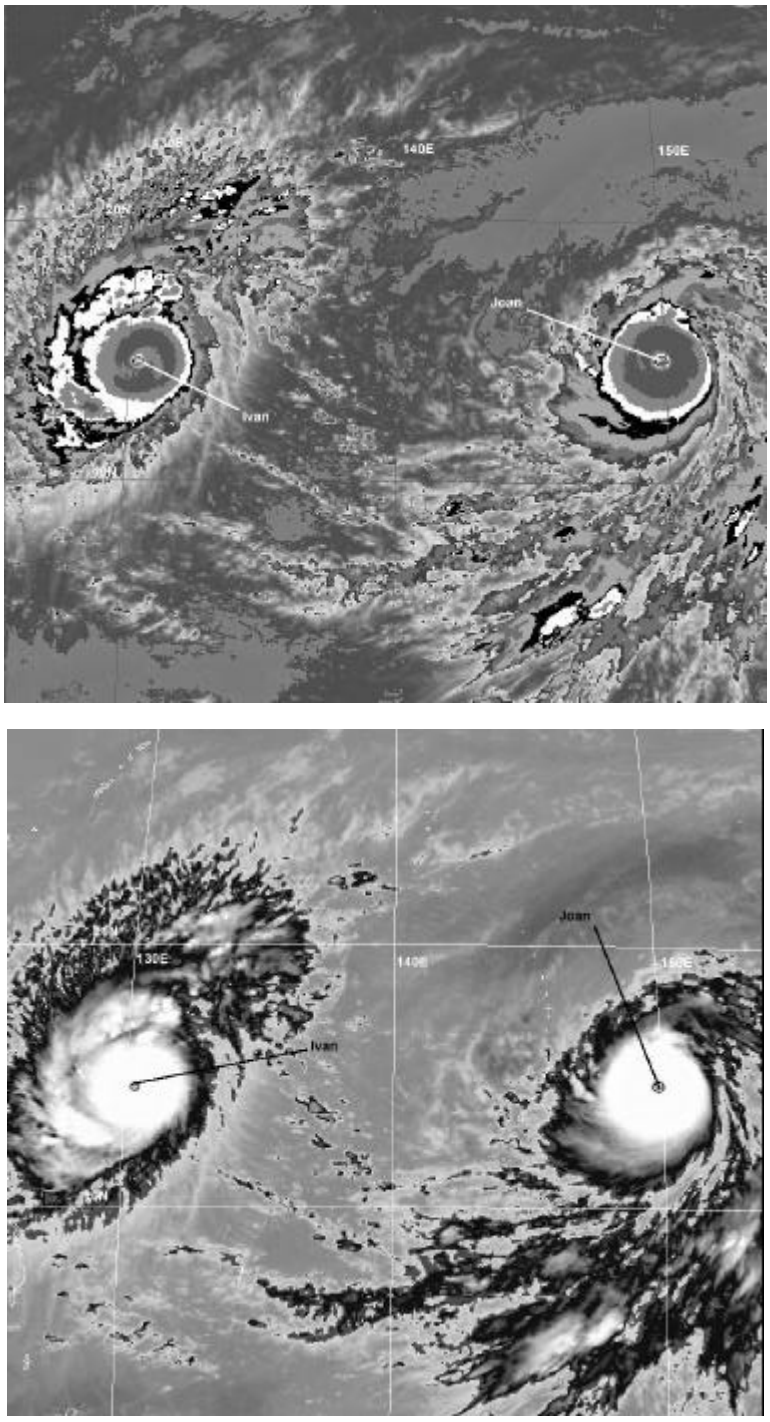


Figure 3-27/28-6 For the first time observed, two spatially proximate super typhoons coexisted in the WNP with near-record intensities. At the time of these images, Ivan is at 145 kt (75 m/sec) intensity and Joan is at 160 kt (82 m/sec) intensity. (170632Z October enhanced IR GMS imagery.) Enhancement curve in (a) is "BD", and enhancement curve in (b) is "MB".

b. TC-TC interactions?

In the Systematic and Integrated Approach to Tropical Cyclone Forecasting (Elsberry 1994) there are three basic modes of interactions between two spatially proximate TCs: 1) direct TC interaction (whereby each TC is advected by the flow of the other); 2) semi-direct TC interaction (whereby each TC is advected by the altered flow between the other TC and the high pressure system on the opposite side); and, 3) indirect TC interaction (whereby the TC to the west induces a ridge between the two TCs which, in turn, imposes an equatorward component to the steering flow on the eastern TC). In order to study the interaction between two TCs, it is best to produce a diagram illustrating the motion of each TC with respect to their centroid. Properties of the centroid-relative motion help to reveal the nature of the interaction (which is not always apparent in the actual earth-relative tracks). In the case of Ivan and Joan, the centroid-relative motion (Figure 3-27/28-8) does not seem to indicate that any form of TC interaction took place.

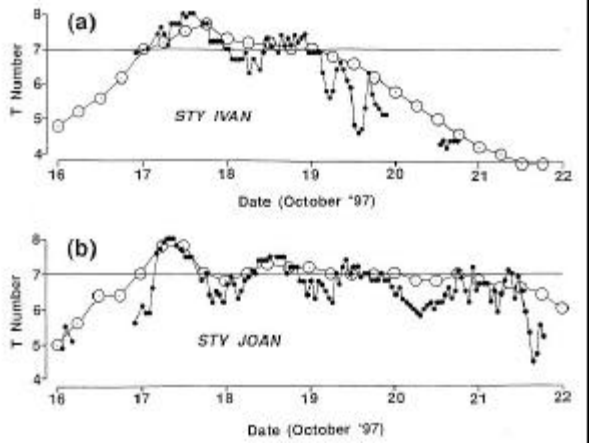


Figure 3-27/28-7 A time series of (a) Ivan's, and (b) Joan's hourly DD numbers (small black dots) compared with the best-track intensity (open circles). Both Joan and Ivan reached an extreme DD magnitude of 8.0 (equivalent to an intensity of 170 kt (87 m/sec)). There is a slight diurnal cycle apparent in these time series with a tendency for higher DD numbers just prior to sunrise (1800Z).

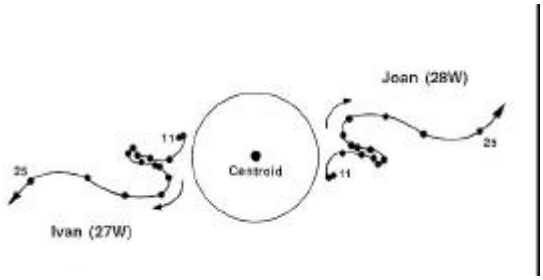


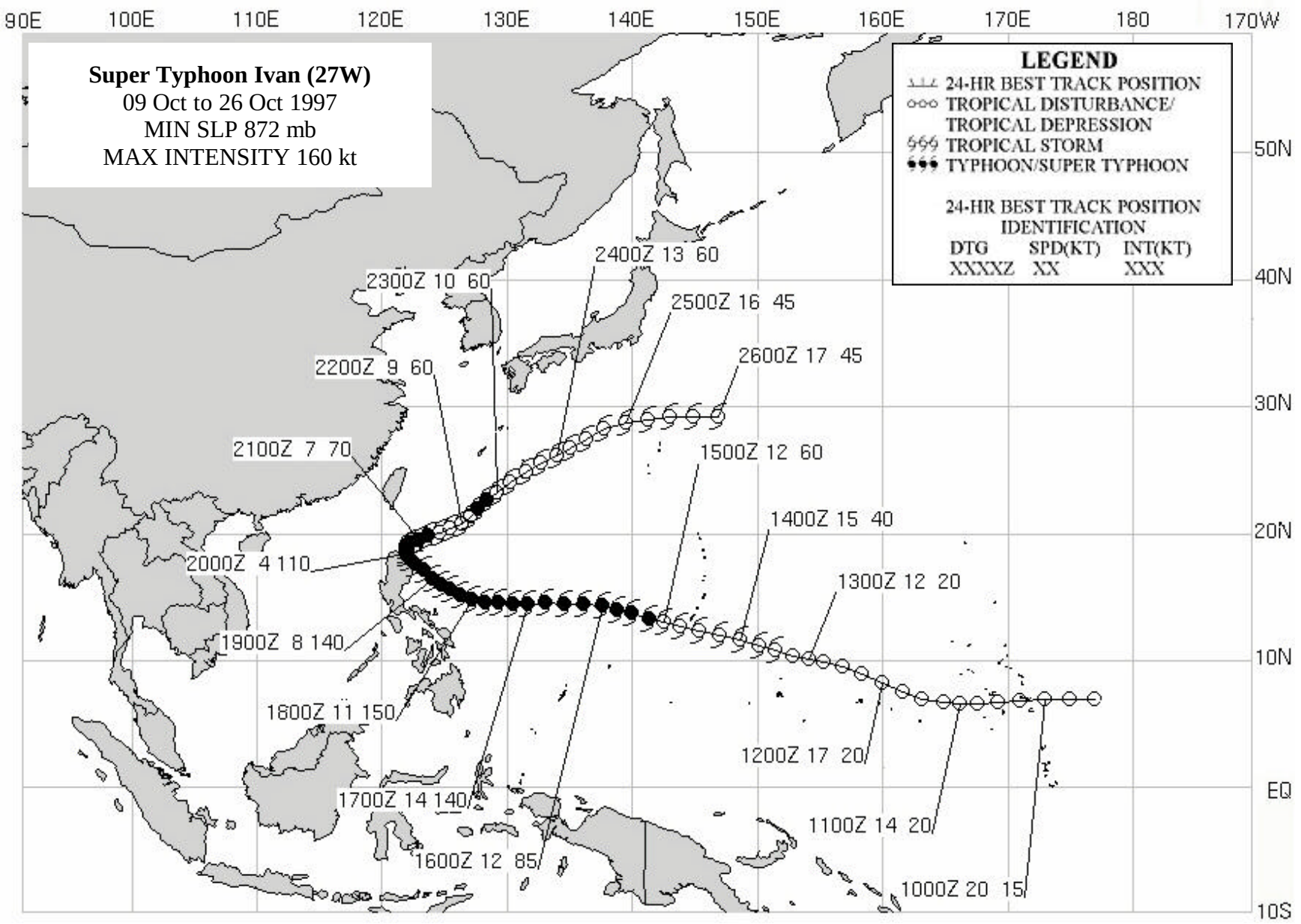
Figure 3-27/28-8 The centroid-relative motion of Ivan and Joan. Black dots indicate positions at 0000Z at 24-hour intervals beginning on 11 October and ending on 25 October. The inscribed circle has a diameter of 600 nm (1100 km).

Although initially within the 780-nm (1446 km) threshold noted by Brand (1970) for mutual cyclonic rotation about the centroid to dominate, very little centroid-relative cyclonic orbit is noted for the period. The common features of TC interaction noted by Lander and Holland (1993) of mutual approach followed by a period of stable cyclonic orbit are also missing. Only the rapid increase of separation distance as the two TCs recurved is a typical feature of binary interaction noted by Lander and Holland. This so-called "escape" phase indicates that the binary interaction has ceased. In summary, Ivan and Joan appear to have undergone no form of TC interaction. They simply moved along similarly shaped adjacent recurving tracks and, recurving

at approximately the same time, the centroid relative motion became one of rapid increase in separation distance as Joan recurved east of Ivan and accelerated faster into the midlatitudes

IV. IMPACT

Both Ivan and Joan affected the Mariana Islands. On the night of 14 October, Ivan passed 55 nm (100 km) to the south of Guam where a peak wind gust of 41 kt (21 m/sec) was recorded at Andersen Air Force Base; the heaviest 24-hr rainfall of 5.85 inches was also recorded at Andersen. Ivan also affected the Philippines. At least one person was reported drowned and another missing on the northeastern tip of Luzon. Ivan damaged thousands of houses and destroyed large amounts of rice and corn in this region. More than $US 500,000 worth of fish stocks in ponds and cages were also destroyed. Joan largely spared the Mariana Islands any significant damage when it passed between the Islands of Saipan and Anatahan on 18 October. Peak wind gusts of 85 kt (44 m/sec) were experienced on Saipan when Joan passed approximately 45 nm (80 km) to the north. A Red Cross initial assessment indicated that Joan destroyed four houses, caused major damage to 15 other tin and wood structures and caused minor damage to 17 homes on Saipan. On Guam, winds gusted to only 33 kt (17 m/sec) at the commercial port on the west side of the island.


Super Typhoon Ivan (27W)
09 Oct to 26 Oct 1997
MIN SLP 872 mb
MAX INTENSITY 160 kt
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XXX
90E
100E
110E
120E
130E
140E
150E
160E
170E
180
170W
50N
40N
30N
20N
10N
EQ
10S
2400Z 13 60
2300Z 10 60
2500Z 16 45
2600Z 17 45
2200Z 9 60
2100Z 7 70
1500Z 12 60
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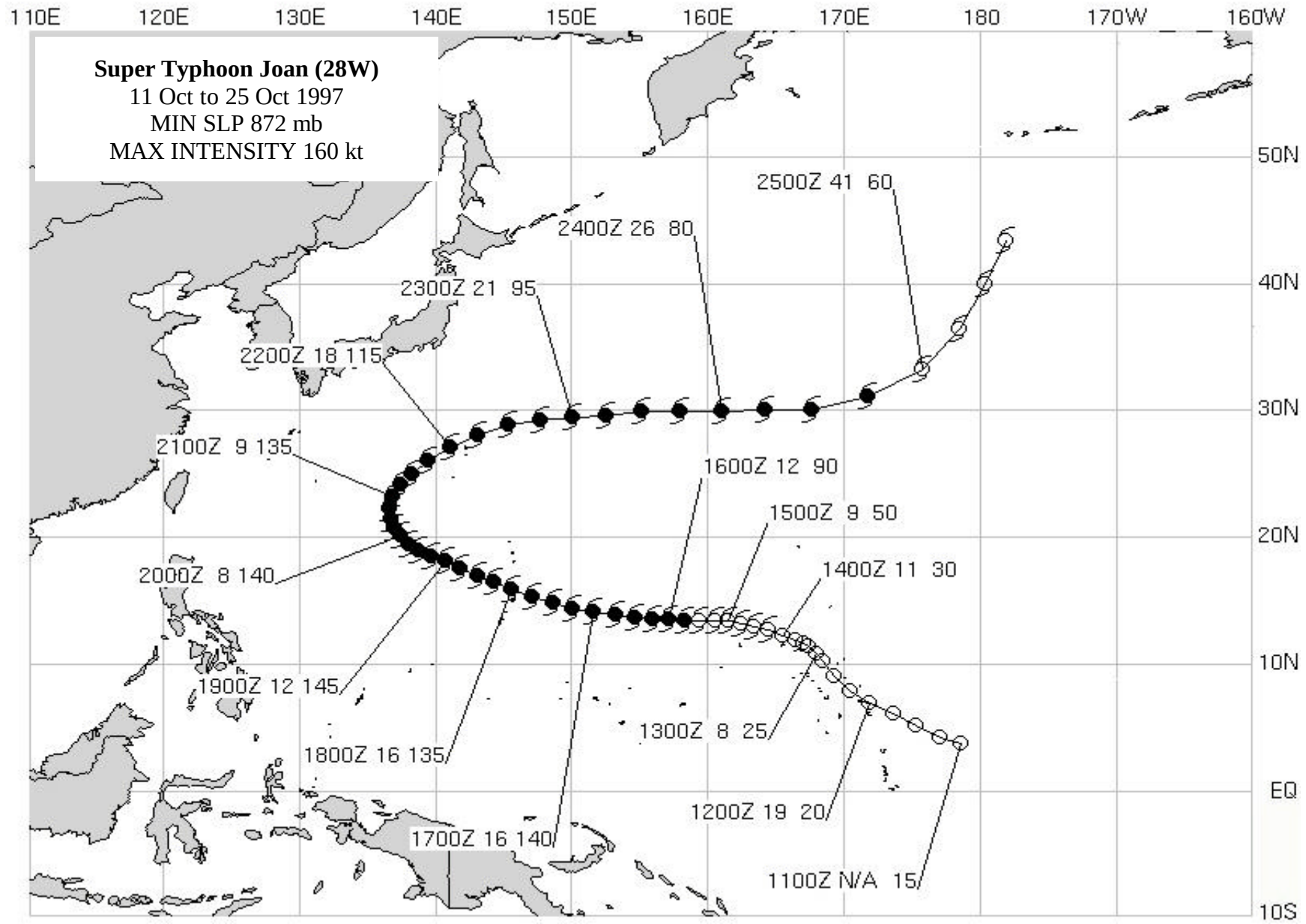
Super Typhoon Joan (28W)
11 Oct to 25 Oct 1997
MIN SLP 872 mb
MAX INTENSITY 160 kt
110E
120E
130E
140E
150E
160E
170E
180
170W
160W
50N
40N
30N
20N
10N
EQ
10S
2500Z 41 60
2400Z 26 80
2300Z 21 95
2200Z 18 115
2100Z 9 135
1600Z 12 90
1500Z 9 50
1400Z 11 30
2000Z 8 140
1900Z 12 145
1300Z 8 25
1800Z 16 135
1200Z 19 20
1700Z 16 140
1100Z N/A 15